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REV: MARCH 8, 2010

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The fuel of the future is going to come from fruit like that sumach [sic] out by the road, or from apples, weeds, sawdust -- almost anything. There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years.

—Henry Ford, to a *New York Times* reporter in 1925[1]

There is one thing all energy transitions have in common: they are prolonged affairs that take decades to accomplish, and the greater the scale of prevailing uses and conversions the longer the substitutions will take.

—Vaclav Smil, in an article in the *The American*[2]

In early 2010, as Dave Summa stared out the window at the snowstorm blowing across the New Hampshire mountains, he thought about the future of Mascoma Corporation. Summa, Mascoma's chief business officer, was finishing a meeting with several members of his business team—Larry Feinberg, John Hannon, and Justin van Rooyen. They had been discussing the merits of the particular projects on which they were working. During its first four and half years, Mascoma, headquartered in Lebanon, NH, had been a biofuel technology firm focused on developing new biochemical processes for producing ethanol. After raising $96.5 MM in venture capital financing and $50 MM in assorted government grants, the company had proven the effectiveness of its proprietary yeasts and bacteria in a pilot-scale biorefinery. Now, as Mascoma embarked on commercializing its production process, it faced numerous strategic, financing, and nonmarket complications that threatened its existence, foremost of which was the dreaded "Valley of Death" across which entrepreneurial ventures had to cross. This was the gap between the funding needed for a demonstration and that needed for a full-scale commercial operation. The gap could require hundreds of millions of dollars, and few sources for such cash existed. As a result, many new energy ventures floundered in this valley, unable to convince investors the reward was worth the investment risk.

Mascoma was one of a few companies that appeared to have the ability to cross this chasm. In the wake of concerns about the dangers of climate change, rising petroleum prices, and energy security, biofuels (ethanol, methanol, biodiesel, and biobutanol) were thought to be part of the solution to the energy crisis. Pushed by government incentives and standards,

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[1] Kovarik B. (1998). Henry Ford, Charles F. Kettering and the Fuel of the Future. *Automotive History Review*, Spring(32): 7–27. Retrieved from www.runet.edu/~wkovarik/papers/fuel.html.

[2] Smil V. (2008). Moore's Curse and the Great Energy Delusion. *The American*, November 19.

Authors prepared this case with the participation of Mascoma personnel, including Dave Summa, Justin van Rooyen, Larry Feinberg, Joseph Donze, and Keith Pattison. Please do not distribute this case for classroom use without approval from Mascoma Corporation.

ethanol had become a leading biofuel in early 2010. Renewable fuel standards from the EPA and E10 blend regulations[3] helped foster the market for ethanol. But ethanol derived from food-based feedstocks, such as corn, had lost political and popular support because production was expensive and tended to drive up food prices. Few analysts thought it likely corn-based ethanol represented a sustainable and economically viable source of energy. Mascoma intended to use other sources to create ethanol. Its approach involved the use of feedstocks that were high in cellulose and low in sugar. Creating ethanol from cellulose (cellulosic ethanol) was a far more difficult enterprise.

As the business development eam left his office, Summa knew he would have to make a recommendation to his CFO, Keith Pattison, about which project the company should push forward. With the board meeting only two days away, Summa reflected on his options and the future of Mascoma.

The Changing Nature of Energy

In his 2009 inaugural address, President Barack Obama called for the expanded use of renewable energy to meet the twin challenges of energy security and climate change, the first time a US president had referred to energy use, renewable resources, and climate change in an inaugural speech. Obama looked to the near future, promising the United States would "harness the sun and the winds and the soil to fuel our cars and run our factories."[4]

In 2008, 57 percent of the petroleum products consumed in the US were imported[5]. (See Exhibit 1 for petroleum import, production, and consumption trends from 1949 to 2008.) This dependency left the US vulnerable to threats to its energy security, including political instability in energy-producing countries, manipulation of energy supplies, competition for energy sources, and general disruption of supply infrastructure. These threats, coupled with uneven distribution and the rising cost of fossil fuels, stimulated demand to shift to sustainable and domestic energy sources. (See Exhibit 2 for oil price information from 1861 to 2008.)

Furthermore, recent findings from climate change studies, specifically greenhouse gas (GHG) emissions, highlighted the need to shift toward more sustainable energy sources. Fossil fuel combustion is a leading source of CO_2 emissions, driven largely by petroleum via car emissions. The global warming potential (GWP) differs among various GHG, and although the GWP for CO_2 is relatively mild, the massive increase in CO_2 caused by the burning of fossil fuels since the Industrial Revolution is now the prime contributor to climate change.[6] Political and public debate regarding climate change, as well as what actions to take in response, continues. Available options include mitigation to reduce further emissions and adaptation to reduce the damage warming causes.

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[3] a blend of 10 percent ethanol and 90 percent gasoline, or lower ethanol blends[3]

[4] US Department of Energy, Energy Efficiency and Renewable Energy. (2009). President Obama Calls for Greater Use of Renewable Energy. Retrieved from http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=12194.

[5] US Energy Information Administration. Energy in Brief: How Dependent Are We on Foreign Oil? Retrieved from http://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm. Note: 2008 data.

[6] Karl TR, Trenberth KE. (2003). Modern Global Climate Change. *Science,* 302(5651): 1719–1723.

Because energy security and climate change have captured national attention, policy makers and consumers alike have pressed for progress on more renewable energy. Renewable energy technologies comprise a diverse array, including solar thermal power, wind power, hydroelectricity, geothermal power plants, and the use of biomass—organic material made from plants or animals. Renewable energy accounted for 10.4 percent of the domestically produced energy in the United States in the first 10 months of 2009.[7]

Biofuels

"Biofuels" are any fuel derived from biomass. There are several types of biofuels, but almost all can be classified as either ethanol or ester (commonly referred to as biodiesel). Ethanol is derived from sugar and starchy crops; ester is derived from oil-seed crops.[8] Ethanol is the most widely used biofuel today. Most often, it is used as an alternative fuel or it is blended with gasoline in varying quantities to reduce consumption of petroleum fuels and reduce air pollution.[9] Almost all ethanol produced is used in cars and trucks, with small quantities used for aviation purposes.[10]

Ethanol is an alcohol made by fermenting the sugar components of plant materials, mainly sugar and starchy crops, such as sugarcane and corn. Unlike petroleum, ethanol is a form of renewable energy, but concerns about overall ethanol production capacity, the use of farmland for biofuel production, and negative environmental impacts have led many people to question the wisdom of replacing gasoline with ethanol. Recent developments in cellulosic ethanol, a second-generation ethanol, may alleviate these concerns by using other sources to produce this biofuel.

One merit of biofuels is that they could improve domestic energy security. The move away from oil-based fuels toward ethanol represents a net shift from foreign to domestic energy sources, potentially lessening our foreign oil dependence and increasing our energy security.

Evolution of the Ethanol Industry

In 1908, Henry Ford produced the Model T, capable of running on gasoline, ethanol, or a combination of both.[11] It is remarkable that as early as the turn of the century, Ford was able to envision a future where the food we grow would power the cars we drive. Although he shared this dream with other leading automakers of his time, the abundance of cheap oil encouraged industry dependence on fossil fuel.[12] Since then, ethanol has come in and out of vogue numerous times because its attractiveness is tied to ever-fluctuating oil supply and demand. Bill Kovarik, author of *Henry Ford, Charles F. Kettering, and the Fuel of the Future*, writes,

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[7] US Department of Energy, Energy Information Administration. (2010). Electric Power Monthly. *Independent Statistics & Analysis*, January. Retrieved from http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html?featureclicked=3&.

[8] International Energy Agency. (2006). *World Energy Outlook 2006*, p. 386.

[9] The Cellulosic Ethanol Site. (year). Cellulosic Ethanol Background and Facts. Retrieved from http://www.thecesite.com/ce_faq.htm.

[10] International Energy Agency. (2006). *World Energy Outlook 2006*: 386.

[11] English A. (2008). Ford Model T Reaches 100. *The Telegraph*, July 25. Retrieved from http://www.telegraph.co.uk/motoring/main.jhtml?xml=/motoring/2008/07/25/mnmodel125.xml.

[12] Kovarik B. (1998). Henry Ford, Charles F. Kettering and the Fuel of the Future. *Automotive History Review*, Spring(32): 7–27. Retrieved from www.runet.edu/~wkovarik/papers/fuel.html.

> American farmers embraced the vision of new markets for farm products, especially alcohol fuel, three times in the 20th century: around 1906, again in the 1930s with Ford's blessing, and most recently, during the oil crisis of the 1970s. By the mid-1980s over one hundred corn alcohol production plants had been built and over a billion gallons of ethyl alcohol were sold per year in the fuel market. In the late 1980s and 1990s, with an apparently permanent world oil glut and rock bottom fuel prices, most of the alcohol plants shut down. Some observers joked that ethyl alcohol was the fuel of the future — and always would be.

In recent years, ethanol has come into the spotlight with renewed vigor, as concerns over energy security, economic stability, and environmental impact have risen to the top of the US agenda. In 2006, Obama, at the time a junior senator from Illinois, referred to Ford's vision:

> More than 80 years later, America's addiction to oil makes it clear that we have to go back to that future. Doing so won't just free us from our dependence on a dangerous and finite fossil fuel, it will also rejuvenate an industry desperate for another chance. [13]

Government Regulations Driving Demand

Ethanol production is rising rapidly in many parts of the world in response to higher oil prices, making ethanol more competitive, especially where reinforced by government incentives and fuel specifications.[14] The world's top ethanol fuel producers in 2008, the US and Brazil, accounted for 89 percent of the world's production, with 9 billion and 6.5 billion liquid gallons respectively[15]. Ethanol is widely used in these two countries, largely due to government incentives and industry regulations that are driving demand. Although ethanol market share was only about 3.4 percent of the US gasoline-vehicle fuel consumption as of 2007[16], domestic production capacity has increased more than tenfold since 1990, growing from approximately 900 million gallons to 9 billion gallons in 2008.[17]

Today, most cars on the road in the US run on E10, a blend of 10 percent ethanol and 90 percent gasoline, or lower ethanol blends[18] E10 is the most common low concentration blend, and its use is mandated in many areas of the US as a replacement for methyl t-butyl ether, which has been found to contaminate groundwater and soil.[19] The Brazilian government has mandated the use of ethanol-blended gasoline since 1976, with the current mandated blend of E20 (20 percent ethanol, 80 percent gasoline).[20] E85, a blend of 85 percent ethanol and 15

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[13] Obama B. (2006). Fueling the Future. *The American Prospect*, March 20. Retrieved from http://www.prospect.org/cs/articles?article=fueling_the_future.

[14] International Energy Agency. (2006). *World Energy Outlook 2006*, 389.

[15] Renewable Fuels Association. (2008). 2008 World Fuel Ethanol Production. Retrieved from http://www.ethanolrfa.org/pages/statistics.

[16] US Department of Energy, Energy Information Administration. Ethanol Market Penetration. Alternative Fuels & Advanced Vehicles Data Center. Retrieved from http://www.afdc.energy.gov/afdc/ethanol/market.html.

[17] Renewable Fuels Association. (year). Historic U.S. Fuel Ethanol Production. Retrieved from http://www.ethanolrfa.org/pages/statistics.

[18] Worldwatch Institute and Center for American Progress. (2006). American Energy: The Renewable Path to Energy Security.

[19] The Cellulosic Ethanol Site. (year). Cellulosic Ethanol Background and Facts. Retrieved from http://www.thecesite.com/ce_faq.htm.

[20] Jessen H. (2010). Ethanol Mandate Lowered in Brazil. *Ethanol Producer Magazine*, January. Retrieved from www.ethanolproducer.com/article.jsp?article_id=6290.

percent gasoline, has been blended effectively, but this ratio is too corrosive for traditional engines. Flex-fuel vehicles, which can withstand much higher ethanol blends than can traditional engines, have been designed to run on any blend up to E85.

The US Environmental Protection Agency (EPA) is responsible for developing and implementing regulations to ensure transportation fuel sold in the United States contains a minimum volume of renewable fuel. The Renewable Fuel Standard program, originally created under the Energy Policy Act of 2005, was modified and finalized on February 3, 2010. These new renewable fuel standards increased the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022.[21]

First-Generation Ethanol

Large-scale farming is necessary to produce agricultural alcohol, diverting substantial amounts of land from growing food to biofuel production, with negatives consequences on the global food supply. This "food vs. fuel" debate is ongoing and global in scale, with valid arguments on all sides.

In 2006, researchers at the University of Minnesota reported that if all corn grown in the US were used for ethanol production, it would displace only 12 percent of current US gasoline consumption[22]. This and similar studies have led many to question the usefulness of diverting scarce land resources, which most likely will drive up food prices without significantly meeting our overall energy demands. While there is some controversy regarding the degree to which biofuels contribute to rising food prices, there seems to be general consensus that there is a causal relationship.

Many consider skyrocketing food prices in recent years, following a period of overall declining prices from 1974 to 2005, extraordinary in nature and link this trend to the growing production of biofuels. A World Bank policy research working paper cited the following increases in food prices:

> The International Monetary Fund's index of internationally traded food commodities prices increased 130% from January 2002 to June 2008 and 56% from January 2007 to June 2008. Prior to that, food commodities prices had been relatively stable after reaching lows in 2000 and 2001 following the Asia financial crisis.[23]

Beyond stating the specific changes in food prices, the report goes on to conclude the degree to which this change was driven by an increase in biofuel production:

> The combination of higher energy prices and related increases in fertilizer prices and transport costs, and dollar weakness caused food prices to rise by about 35–40 percentage points from January 2002 until June 2008. These factors explain 25–30 percent of the total price increase, and most of the remaining 70–75 percent increase in food commodities prices was due to biofuels and the related consequences of low grain stocks, large land use shifts, speculative activity and export bans. It is difficult, if not impossible, to compare these estimates with estimates from other studies

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[21] US Environmental Protection Agency. (year). Renewable Fuels: Regulations & Standards. Retrieved from http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm.

[22] Morrison D. (2008). Ethanol Fuel Presents a Corn-undrum. University of Minnesota News. Retrieved from http://www1.umn.edu/news/features/2006/UR_101631_REGION1.html>>

[23] Mitchell D. (2008). A Note on Rising Food Prices. The World Bank Development Prospects Group, July: 2.

> because of different methodologies, widely different time periods considered, different prices compared, and different food products examined, however most other studies have also recognized biofuels production as a major factor driving food prices.[24]

In addition to debates regarding the impact on the global food supply, first-generation ethanol has also been criticized for having a negative local environmental impact (caused by the use of pesticides, etc.).

Second-Generation Ethanol

A second generation of ethanol has emerged in response to many of the concerns surrounding first-generation corn-based technologies. Cellulosic ethanol is a new approach that may alleviate land use and related concerns. In contrast to sugars or starches from fruits and grains, cellulosic ethanol is obtained from cellulose, the main component of wood, straw, and plant structure.

Both first- and second-generation ethanol are made by fermentation. However, because cellulose has a wider variety of molecular structures, fermentation requires a wider variety of microorganisms to break them down. Furthermore, the raw plant matter must be pretreated to make the cellulose accessible to these microorganisms. The pretreatment and fermentation processes are being studied in labs across the country, but, at this time, cellulosic ethanol is not manufactured on an industrial scale.[25] The International Energy Agency commented on the increasing potential of cellulosic ethanol in its World Energy Outlook report:

> New biofuels technologies being developed today, notably enzymatic hydrolysis and gasification of woody ligno-cellulosic feedstock, could allow biofuels to play a much bigger role than that foreseen in either scenario. Ligno-cellulosic crops, including trees and grasses, can be grown on poorer-quality land at much lower cost than crops used now to make biofuels. They may also be more environmentally benign. But significant technological challenges still need to be overcome for these second generation technologies to become commercially viable.[26]

The obvious advantage of cellulosic ethanol is its dependence on abundant and diverse raw materials rather than traditional feedstocks. Because humans cannot digest cellulose, producing it does not directly compete with food production. In fact, fast-growing species, like switchgrass, can be grown on land not suitable for corn or other cash crops. Byproducts of other agricultural activities such as straw or wood chips can be converted to ethanol. Of the many possible biomass sources, switchgrass is one of the leading materials being studied due to high-productivity yields per acre. Furthermore, exploiting the cellulose in corn plants, rather than just using the kernels as in first-generation ethanol, could double corn's ethanol yield.[27]

In addition to independence from foreign oil and lower impact on global feedstocks, another benefit cellulosic ethanol offers is lower GHG compared to both first-generation ethanol and

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[24] Ibid, 17.

[25] Hammerschlag R. (2006). Ethanol's Energy Return on Investment: A Survey of the Literature 1999–Present. *Environmental Science & Technology*, 40(6): 1744–1750.

[26] International Energy Agency. (2006). *World Energy Outlook 2006*: 385.

[27] Bourne JK Jr. (2007). Green Dreams. *National Geographic Magazine*, October.

traditional petroleum. According to US Department of Energy (DOE) studies conducted by the Argonne National Laboratory, cellulosic ethanol reduces GHG by 85 percent compared to reformulated gasoline, a dramatic improvement upon first generation, which uses natural gas, and may not reduce GHG emissions at all depending on how it is produced[28]. Roel Hammerschlag, a researcher at the Institute for Lifecycle Environmental Assessment, studied ethanol's energy return on investment and concluded that cellulosic ethanol can displace more nonrenewable energy than can corn ethanol.

> Comparing the r_E values (ratio of energy in a liter of ethanol to the nonrenewable energy required to make it) indicates that cellulosic ethanol displaces profoundly more nonrenewable energy than corn ethanol. The effect on greenhouse gas emissions will probably be even more pronounced, since the agricultural practices tied to cellulosic ethanol are typically less likely to produce CH_4 and N_2O. Examination of a proper land-use indicator will probably also show cellulosic ethanol to beat corn ethanol, because the whole-plant approach can take advantage of greater per-hectare yields than are possible for shelled corn. Last, the substantial oil displacement of both corn and cellulosic ethanol is not offset by increases in other fossil fuels when the ethanol is cellulosic.[29]

It is estimated that 323 million tons of raw materials containing cellulose are thrown away each year in the US alone. This includes 36.8 million dry tons of urban wood wastes, 90.5 million dry tons of primary mill residues, 45 million dry tons of forest residues, and 150.7 million dry tons of cornstalks and wheat straw[30]. Reducing disposal of solid waste through cellulosic ethanol conversion would reduce solid waste disposal costs by local and state governments.

As advancements continue to be made, cellulosic ethanol production edges closer toward becoming economically feasible in the US. Leading the pack of second-generation technologies, cellulosic ethanol potentially could become a competitive energy resource; however, additional financial support is essential to develop the necessary infrastructure.

Mascoma's Challenge

In the summer of 2005, Mascoma was founded by two noted academics, Charles Wyman and Lee Lynd, of the Thayer School of Engineering at Dartmouth. Wyman and Lynd were considered leading experts on the conversion of biomass to alternative fuels and wrote several seminal works on the subject. Named after Mascoma Lake in nearby Enfield, NH, the company concentrated on improving the effectiveness of bacteria and yeast used in the ethanol production process through genetic engineering. By creating bacteria and yeast that could both produce the enzymes necessary to hydrolyze cellulose into simple sugars and ferment the resulting slurry in one step—referred to as consolidated bioprocessing (CBP)—the company believed it could reduce the capital costs to build biorefineries and save on operating expenditures related to purchasing enzymes from third parties.

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[28] Environment California. (2007). Clean Cars, Cool Fuels. Fall Report, 5(2). Retrieved from https://www.environmentcalifornia.org/newsletter/fall07/clean-cars-cool-fuels.

[29] Hammerschlag R. (2006). Ethanol's Energy Return on Investment: A Survey of the Literature 1999–Present, *Environmental Science & Technology*, 40(6): 1744-1750.

[30] Biomass Resource Estimates. Retrieved from http://bioenergy.ornl.gov/papers/misc/resource_estimates.html.

By September 2006, Mascoma had raised $5.25 MM in two seed-financing rounds from Khosla Ventures and Flagship Ventures, two noted venture capital firms that were investing heavily in the clean tech space. (See Exhibit 4 for Mascoma's funding history.) After initial laboratory experiments proved promising, Mascoma raised an additional $30 MM in a C round of venture financing to further expand the company's technology to a pilot-stage plant.[31] Before this facility was built, Mascoma acquired Celsys BioFuels, based out of Purdue University, which held patents on proprietary pretreatment processes for multiple biomass feedstocks, including the ability to move into traditional corn-based ethanol facilities. In addition, Mascoma brought in Michael Ladisch to be the chief technology officer.

In June 2008, Mascoma opened its biomass-to-ethanol pilot plant in Rome, NY, with the financial assistance of a $14.8 MM grant from the NY State Department of Agriculture & Markets and the NY State Energy Research and Development Authority. This plant would run 1,000 gallon– and 5,000 gallon–scale trials based on processes and proprietary organisms created at the laboratories in Lebanon. Around this time, Mascoma also received attention from corporate sponsors, including General Motors and Marathon Oil, which invested $10 MM in the firm to produce low-carbon biofuel.[32]

After raising an additional $61 MM in venture financing in 2008, Mascoma began plans for its first full-scale demonstration and commercial facility.[33] Scheduled to open in 2012 in Michigan's Chippewa County, the facility received a $26 MM grant from the Department of Energy and a $23.5 MM grant from the state of Michigan through the Michigan Economic Development Services. The plant is structured as a joint venture between Mascoma and J. M. Longyear, a natural resources company that owns 73,000 acres of forest land in Michigan's upper peninsula. The JV, Frontier Renewable Resources, initially plans to open as a 20 million gallons/year and scale to 40 million gallons/year by 2013.

In May 2009, Mascoma announced a major breakthrough in its proprietary CBP process, resulting in increased yields using cellulosic feedstocks. The company has proven the success of its proprietary microorganisms, including a 60 percent increase in the ethanol conversion efficiency of thermophilic bacteria and a 3,000-fold increase in enzymatic expression of cellulolytic yeast.[34] Additionally, the technology reduced the amount of organic acid byproducts produced during fermentation and lowered the amount of added cellulose needed in the ethanol production process.

Traditional Ethanol Fermentation Process

Ethanol production is produced through a multistep process in a closed-loop biorefinery. Two divergent processes are used in ethanol production: fermentation and gasification. Fermentation involves breaking down feedstocks into sugar slurries using either physical or biochemical means and fermenting the mixture using bacteria and yeast. The traditional fermentation process is known as "simultaneous saccharification and co-fermentation" (SSCF) with cellulase production. (See Exhibit 5 for process flow diagram of ethanol fermentation.) Gasification involves the heating of feedstocks through thermochemical

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[31] VentureXpert. New investors included Atlas Venture, Kleiner Perkins Caulfield & Byers, VantagePoint Venture Partners, General Catalyst Partners, and Pinnacle Ventures.

[32] Mascoma Corporation. Retrieved from http://www.mascoma.com.

[33] VentureXpert

[34] Mascoma Corporation. (2009). Mascoma Announces Major Cellulosic Biofuel Technology Breakthrough. Press Release, May 7.

means to produce synthetic gas that is then converted into ethanol through catalytic synthesis.

The major process steps for a fermentation plant are as follows[35]:

- Pretreatment – Starchy feedstocks are broken down into component parts in preparation for hydrolysis. In a dry milling process, which is predominantly used in first-generation corn-based ethanol facilities, the feedstock is ground into flour and combined with water to make a mash. In wet-milling processes, feedstocks are combined with water and broken down into simpler parts using chemical processes, such as acid hydrolysis, fiber expansion, or alkaline wet oxidation. Pretreatment is an expensive step that can create harmful byproducts, such as furfural, that inhibit bacteria and yeast fermentation.

- Hydrolysis – Using enzymes, the mash from the pretreatment phase is broken down further into component sugars, such as glucoamylase and alpha-amylase, or acids. The enzymatic processes can be done at milder temperatures without the formation of harmful byproducts. Several companies have specialized in producing enzymes specifically designed for hydrolyzing different feedstocks. During this phase, residual solids, including lignin, are separated and can be sold as byproducts or used to run onsite power facilities.

- Fermentation – The slurry from the hydrolysis phase undergoes an anaerobic process in which the sugars are converted into ethanol and carbon dioxide through microbes. Traditionally, yeast has been used to convert the sugars, but more recently, companies have been exploring new types of yeasts and bacteria to use in combination for the fermentation process. Part of this innovative process is the result of the need to find new microorganisms to convert more complex sugars, xylose and arabinose, which are present in cellulosic feedstocks. The CO_2 released during this process can be captured and sold for manufacturing processes.

- Distillation – The brew from the fermentation process is separated and concentrated into 95 percent pure alcohol, water, and other residues. Ethanol must be 95.6 percent by volume to be effective as a mobile fuel. Residue from the distillation process can also be used in the onsite steam boiler for plants' electricity and steam needs.

- Dehydration – The resulting alcohol-water mixture is passed through molecular sieves to further absorb water and bring the ethanol mixture to 99.5 percent by volume. At this stage, denaturing agents are added to the ethanol mixture to render it unfit for consumption.

Consolidated Bioprocessing

Mascoma's competitive advantage, consolidated bioprocessing, provides an alternative fermentation process that vastly improves the efficiency and performance of ethanol production. CBP involves combining cellulose production, hydrolysis, and fermentation in one single step by genetically engineering microorganisms to exhibit cellulose expression and

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[35] Renewable Fuels Association. (year). How Ethanol Is Made. Retrieved from http://www.ethanolrfa.org/pages/how-ethanol-is-made.

fermentation capabilities. After feedstocks are pretreated, the resulting mash can be passed through the CBP process and then on to distillation and dehydration.

Developing CBP involves two strategies in creating proprietary microorganisms. The native cellulolytic strategy involves genetically engineering microorganisms that exhibit high cellulase production to improve fermentation properties, such as yield and titer.[36] These microorganisms include the anaerobic bacteria *Clostridium cellulolyticum* and *Clostridium thermocellum*. The recombinant cellulolytic strategy involves genetically engineering strong fermentation-performing microorganisms to express a cellulase production system.[37] The microorganisms that are used for the recombinant strategy include the bacteria *E. coli* and the yeast *Saccharomyces cerevisiae*.

CBP provides three distinct advantages over SSCF:

- Reduced capital and operating costs – By combining processing steps, Mascoma can save on capital expenditures related to building out separate equipment for onsite cellulase production, hydrolysis, and fermentation. (See Exhibit 7 for a cost comparison of CBP and SSCF.) Mascoma estimates it can save $25–$30 MM in capital costs at a full-scale biorefinery. Additionally, the company will save on purchasing enzymes and yeasts from third parties as it can propagate microorganisms and produce enzymes on its own. Enzymes and yeast are the second most expensive input in a biorefinery, amounting to $15 MM annual cost in a 40 MM gallons/year biorefinery.[38]

- Improved productivity yields – Mascoma's proprietary microorganisms have been genetically engineered to express higher cellulase titers than commercially available microorganisms. Further, Mascoma's use of multiple microorganisms targeted at different sugars allow for a more complete conversion of cellulosic feedstock, including more complex sugars, such as xylose and arabinose. The company estimates its microorganisms can improve productivity yields in existing corn ethanol plants 12–35 percent.

- Flexibility of feedstocks – Mascoma's microorganisms have been shown to work across a broad spectrum of feedstocks—specifically, non-food-based cellulosic feedstocks, such as hardwood; switchgrass; and waste products, such as paper sludge. Further, the microorganisms work on food-based feedstocks, such as corn and wheat, as well as plant parts not traditionally subject to ethanol conversion, such as corn stalks. Biomass feedstocks differ in both energy content and amount of carbon dioxide offset in the production process. (See Exhibit 8 for a comparison of feedstock attributes.) This feedstock flexibility allows Mascoma to be opportunistic and pursue feedstocks such as hardwood that are less subject to commodity price swings.

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[36] Lynd LR, van Zyl WH, McBride JE, Laser M. (2005). Consolidated Bioprocessing of Cellulosic Biomass: An Update. *Current Opinion in Biotechnology*, 16(5).

[37] Ibid.

[38] Current prices for yeast range from $1 to $3 per pound and for enzymes from $3 to $5 per pound. Based on information provided by Mascoma Corporation.

The Competitive Landscape

By early 2010, the ethanol industry was marked by overcapacity from first-generation ethanol producers and numerous second-generation cellulosic ethanol companies looking to scale to full production. The space also was filled with numerous agriculture technology firms focused on producing high-yield biomass crops, such as switchgrass or miscanthus, and specialty enzyme companies providing inputs for ethanol producers. All these companies were working on filling out the ethanol value chain, which was largely a work in progress.

First-generation ethanol players continue to be the only full-scale producers in the industry today. After the explosive growth in the number of ethanol plants from 2004 to 2008, new plant starts stalled because of the considerable overcapacity (see Exhibits 9 and 10) [39]. As plants under construction prior to the financial crisis have come online, numerous other plants have begun to go idle. Diversified energy companies and refineries have been able to purchase distressed plants at cheap prices (see Valero's purchase of seven plants from VeraSun, which entered Chapter 11 bankruptcy, for $477 MM in March 2009).[40] At the same time, several first-generation ethanol companies, such as POET and Abengoa Bioenergia, have become entrenched competitors looking to expand into second-generation technologies. Outside the US, the ethanol industry in Brazil, based on sugarcane feedstocks, has built considerable capacity, but steep tariffs of $0.54 per gallon on the country's imports have prevented it from becoming a significant competitor in the US.

Numerous firms have entered the second-generation ethanol game, addressing many of the sustainability and cost issues related to first-generation ethanol producers. These companies are taking a variety of innovative approaches to opening up cellulosic ethanol production, backed by considerable funds from the venture capital industry.[41] (See Exhibit 10 for an overview of the second-generation biofuel landscape.) Some companies, such as Verenium and Iogen, are competing directly with Mascoma to perfect CBP. Also in this space are large chemical conglomerates, such as DuPont, which joined with biotechnology firm Genencor tp create DuPont Danisco Cellulosic Ethanol LLC. Some companies, including Range Fuels and Enerkem, are taking a gasification approach with catalytic synthesis that will compete directly with Mascoma. By early 2010, no second-generation commercial biorefineries were online. However, numerous companies working with the US Department of Energy and various state agencies built out pilot and demonstration plants. Approximately 30 pilot and demonstration plants have been built or received preliminary funding through the DOE Energy Efficiency and Renewable Energy Biomass Program (see Exhibit 11).[42] Several companies currently are in the market to obtain financing for their first full-scale commercial plants. Verenium has progressed the most; its proposed plant in the Southeast US is proceeding to advanced due diligence stages with the DOE for loan guarantees worth 80 percent of the invested capital.

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[39] Renewable Fuels Association. (year). The Industry – Statistics. Retrieved from http://www.ethanolrfa.org/pages/statistics

[40] Krauss C. (2009). Valero Energy, the Oil Refiner, Wins Auction for 7 Ethanol Plants. *The New York Times*, March 18. The cost per full-scale biorefinery costs between $200 and $400 MM.

[41] According to VentureXpert Database, mobile fuels companies have attracted over $1 B in financing since 2005.

[42] DOE EERE Biomass Progam. (year). IBR and Targeted Fuel Outputs. Slideshow.

At the same time, other companies are pursuing other types of fuel as alternatives to ethanol. These fuels include other alcohol-based fuels, such as biobutanal and methanol, and bio-based hydrocarbons, such as biodiesel, biogasoline, and bio-jet fuel. Each of these fuels can serve as a alternative to petroleum-based fuel, although the technologies, cost structures, and energy content of the fuels vary widely (see Exhibit 12). Some of the more advanced companies approaching commercialization include Gevo, making biobutanol, and Virent Energy Systems, making an assortment of biopetroleum products. At the same time, so-called third-generation biofuel companies based on algae technologies have attracted considerable venture financing. Recently, Exxon helped launch the $300 MM algae startup Synthetic Genomics, with J. Craig Venter of human genome fame. Given the infancy of the biofuel industry, it is impossible to predict which fuel or combination of fuels will be the winning technology. However, the industry generally concedes that the government will play a considerable role in helping to advance certain fuels. Recently, for example, the US Congress failed to extend the $1.01 per gallon credit for biodiesel producers, delivering a blow to companies dependent on this incentive.

Other companies are taking a more focused approach to the ethanol space by addressing specific parts of the value chain, from bio-crop production to enzyme inputs. These companies are addressing a specific aspect of the ethanol production process: selling inputs to ethanol producers. Companies such as Ceres use advanced plant breeding and biotechnology to develop improved energy crops with higher energy contents and yields. More important to Mascoma's technology, companies such as Novozymes and Genencor are manufacturing and mass producing cellulase enzymes for traditional fermentation. These companies are singularly focused on addressing a specific niche and drastically reducing prices, which could cause competitive concerns for Mascoma.

Finally, at the end of the value chain are the potential off-takers of the ethanol, which could include diversified hydrocarbon companies, refiners, and chemical companies. To date, these companies have not locked themselves into long-term contracts with ethanol producers because of ethanol price volatility, overcapacity, and minimal ethanol requirements relative to their overall production. However, they have been getting more involved in pursuing research and development opportunities with the new generation of biofuel companies. Mascoma has received funding from Marathon Oil and General Motors and has pursued research programs with other large diversified energy companies. Many of the biofuel companies, including Mascoma, have concerns about the commitment of these off-takers. While the biofuel companies want to move quickly toward commercialization, the energy companies are viewing biofuels with a longer time horizon.

Project Opportunities[43]

Even though Mascoma is in the midst of building a demonstration plant in Michigan, it has begun building its strategy to commercialize its ethanol technology. The company has a couple options to pursue several full-scale production projects and an option to concentrate on selling and licensing its proprietary microorganisms to existing ethanol facilities. All these opportunities are considered against the baseline project (see below).

Baseline Project

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[43] All information in this section is based on data and interviews provided by Mascoma Corporation.

Since its founding, Mascoma has focused on building full-scale greenfield biorefineries using its propriety CBP process. The baseline case for this project is a 50 MM gallon/year ethanol refinery based on hardwood as feedstock, supplied through a creditworthy natural resources company under a long-term contract. Even with reduced capital costs, a greenfield facility will require significant capital expenditures of $330 MM. This estimate includes the cost for power facilities that will burn residual lignin and nonconvertible solids from the hardwood feedstock to provide electricity and steam for the plant. Excess power will be sold under contract to the power grid. Operating expenditures will be composed mostly of feedstock costs and other inputs, such as materials for enzymatic and yeast propagation. (See Exhibit 13 for the pro forma for this facility.)

As with most biorefinery plants funded on a project finance basis, the major risks for lenders include commodity price risk of feedstock and off-take products and technology risk. Unlike corn prices, hardwood, as a nonfood feedstock, is less subject to volatility. However, the value of the project is highly variable based on assumptions used for ethanol prices. For purposes of analysis, Mascoma assumes ethanol prices will be $2.25/gallon on average in 2010 and escalate at 3 percent annually. With the success of its pilot plant in Rome, NY, and with additional operating history from the demonstration plant, Mascoma believes it can assuage technology concerns. Still, the first plant is likely to experience far less debt capacity than future plants. For purposes of valuation, Mascoma assumes it will only be able to finance 50 percent of the baseline project with debt, relying on preferred equity holders and off-takers to finance the remaining 50 percent with preferred equity.

Mascoma is confident it can receive a whole suite of government incentives to help make this project attractive to potential investors. With onsite power production, the company can realize power-specific government incentives, such as renewable energy credits (RECs), investment tax credits for open-loop biomass systems, and additional carbon credits. Although Mascoma has based its valuation on securing these government incentives, it is aware of the uncertainty of nonmarket mechanisms, including the US Congress not renewing tax credits or removing renewable fuel standards. Government incentives would play a critical role in helping to secure financing for this first commercial plant, as Mascoma was uncertain the plant could stand on its own at the current price level of ethanol.

At the pivotal meeting with Summa in early 2010, business team members John Hannon, Larry Feinberg, and Justin van Rooyen presented the conclusions they had reached in their respective projects:

Option 1: Sugarcane Bagasse Plant

Hannon recommended an alternative option to the baseline plant that could stand on its own without government incentives. He had been working with a large diversified foreign oil company to set up an ethanol refinery at a sugar factory in the Southeastern US. Instead of running on hardwood as the base feedstock, this plant would run on sugarcane bagasse, the fibrous residue from sugar production. Sugarcane works well as a feedstock for ethanol production, even reducing greenhouse gases per gallon more than corn-based ethanol.

The plant would be co-located on the sugar mill property and would not require an onsite power unit. Instead, the plant would draw power from the local electric utilities and share steam operations with the mill. The entire operation would reduce the capital costs of the plant by two-thirds, to $105 MM. The benefit of the sugarcane operation was that its operations were expected to generate a positive return over the capital investment without the need for government incentives. Hannon believed that even in tight credit markets, Mascoma would be able to increase the debt capacity of the project to 60 percent. The debt capacity was expected to be bolstered by the sponsorship of a creditworthy oil refiner as an off-taker and a stable base of feedstock supply from the sugar mill. (See Exhibit 14 for the pro forma financials.)

Summa was impressed by Hannon's work and intrigued by plant's potential. However, he had several reservations about the project. First, Mascoma would have to perform more research into optimizing the proprietary microbial process for sugarcane as a feedstock. Summa felt this could delay the plant's operations by up to a year. Second, there was not as much sugarcane feedstock available to warrant building a plant much larger than the Michigan demonstration plant. Hannon predicted the co-located sugarcane plant would only have a capacity of 28 MM gallons/year, far less than the baseline project. And, unlike Brazil, the US did not have a significant supply of sugarcane, limiting the opportunities for Mascoma to transfer its work on sugarcane to future plants. This situation was exacerbated by the rush by other second-generation ethanol producers to start sugarcane-based plants.

Option 2: Hardwood Greenfield Plant in Alberta, CA

Feinberg suggested Mascoma consider moving outside the US, where it potentially could find lower-cost hardwood feedstocks. His proposal was to build an ethanol plant in northern Alberta in Canada, which was abundant with hardwood forests. The trees available in Canada could be secured at lower cost than in the US because the target species could be harvested without damaging the remaining root structures. The trees had the added benefit of higher energy contents than available US hardwood, which would increase the yields per ton of feedstock.

These feedstock benefits were expected to make the economics of a hardwood greenfield plant more attractive. Feinberg estimated the capital costs would be similar, at $330 MM spread over a two-year construction period, and would include an onsite power unit. (See Exhibit 15 for the pro forma financials.) The project had strong backing from the Alberta provincial government, which was expected to provide $25 MM in grant funding and loan guarantees for up to 40 percent of the capital costs. Mascoma was certain it could find an off-taker in the US that would be willing to put in the equity financing. Given the large capital costs and inherent technology risk, however, Feinberg estimated the project would have a debt capacity of 50 percent.

Although Summa was encouraged by Feinberg's proposal, several aspects of the project did not sit well with him. First, the location of the project was far north, near High Level, Alberta. Summa wondered whether the expense of building a plant this far north would add to capital costs and whether the plant could withstand the brutal climate over the long run. Second, government incentives for ethanol and power production were not as robust in Canada. Mascoma could not rely on renewable identification number credits (RINs), RECs, and ethanol-based production tax credits that were available in the US. Finally, ethanol prices in Canada were lower than prices in the US because Canada's fuel standards were not as restrictive. Summa worried that despite the benefits of better hardwood feedstock and even after factoring in government incentives, the project might not be profitable.

Option 3: Commercialization of Proprietary Microorganisms

Van Rooyen proposed Mascoma take a different strategy altogether. He felt the company should abandon the attempt to be a full-scale ethanol producer given the current overcapacity in the market and unfavorable credit markets for obtaining reasonable financing. Instead, he argued, the company should focus on commercializing and selling its proprietary microorganisms as products to existing ethanol producers. Even if Mascoma did not want to give up the production strategy, van Rooyen felt the product commercialization strategy might be the best way to realize positive revenues in the short term.

Mascoma already had proven its microorganisms could work across a wide range of biofuels and increase yields by converting more sugars to ethanol, including the more complex sugars. The company estimated it could release several versions of the microorganisms, as its own R&D process continued to increase yields and titers. Currently, Mascoma's microorganisms could improve ethanol yields in existing corn-based ethanol plants by 6 percent. This increase in ethanol, along with reduced costs of buying enzymes from third parties, could drive up the earnings of existing corn-based plants by 15.8 percent. Since Mascoma's microorganisms propagated their own enzymes, ethanol producers could reduce the amount of enzymes they needed to purchase. Mascoma was certain it could capture some of this value in the pricing of microorganism products. The added benefit of this product commercialization strategy is that it did not require significant financing and potentially could avoid debt financing altogether. (See Exhibit 16 for the pro forma financials.)

Even though product commercialization looked attractive in the near term, Summa was not sure this wholesale strategic change would be in Mascoma's best interests. First, the company was not geared to be a manufacturer of inputs for the ethanol process. Doing so would require significant investments in new personnel and facilities that were not available currently. Second, the strategy change would not sit well with the roster of VC investors, who invested in Mascoma as an ethanol producer. The returns expected from a product commercialization strategy were expected to be far smaller than what could be experienced in full-scale production. This was particularly problematic to VC investors who needed a return on the $96.5 MM they already had at risk. Finally, Summa was uncertain how much of the existing ethanol production market they could penetrate—or how quickly. The market for enzymes and yeast already was crowded with companies, putting downward pressure on prices. Some of these companies were divisions of large diversified biotech firms, such as DuPont Danisco Cellulosic Ethanol LLC.

Government Incentives

Although national circumstances vary greatly in every country, strong government support has been in place in the US to spur industry development and bridge the gap between market value and production cost.[44] Federal and state government policy and regulation of biofuels will affect the development of the biofuels industry, both now and in the future. A number of federal and state policies are aimed at reducing the cost of biofuels, increasing availability, and ensuring continued market demand during periods of low petroleum prices. In addition to the ethanol fuel and biofuel production standards mentioned earlier, there are additional incentives featured in the Energy Policy Act of 2005 and the American Recovery and Reinvestment Act of 2009 (ARRA) specifically designed to spur cellulosic ethanol production. These incentives include[45]

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[44] International Energy Agency. (2006). *World Energy Outlook 2006*: p 397.

[45] The Cellulosic Ethanol Site. (year). Cellulosic Ethanol Background and Facts. Retrieved from http://www.thecesite.com/ce_faq.htm.

- creation of a credit program, where 1 gallon of cellulosic biomass ethanol = 2.5 gallons of renewable fuel,
- creation of cellulosic biomass program of 250 million gallons in 2013,
- creation of a loan guarantee program of $250 million per facility,
- creation of $650 million grant program for cellulosic ethanol,
- biomass research and development spending targets.

Some of the specific tax incentives, direct subsidies, and financing guarantees that potentially could affect Mascoma's projects include the following:

- Production Tax Credits (PTCs) – Ethanol facilities are eligible to receive $0.56 per gallon tax credit through the US Treasury for each gallon of ethanol they produce. Facilities generating electricity onsite through green biomass inputs, such as lignin, are also eligible for 1.1¢ tax credit per kWh produced as open-loop biomass systems. In a measure to spur immediate capital investment, the ARRA allows companies to forgo all future PTCs in return for a grant from the US Treasury equal to 30 percent of their installed capital costs.

- Accelerated Depreciation – The Energy Policy Act and ARRA allow qualified renewable technology projects to realize an accelerated depreciation schedule that increases tax benefits in the early years of a project. Specifically, companies can write off 50 percent of the capital costs in the first year, then depreciate the asset at the normal Modified Accelerated Cost Recovery System (MACRS) schedule thereafter.

- Renewable Identification Number (RIN) Credits – This EPA program, under the Renewable Fuel Standard program, acts as a direct subsidy to ethanol producers for each gallon of ethanol that is blended into gasoline. The purpose of the program is to ensure refiners are blending ethanol through tracking numbers on each gallon of ethanol produced. The final RIN credit is supposed to be handed over to the ethanol producers. An EPA formula sets the size of the RIN credit each year. Current estimates of the RIN credit amount to $0.25 per gallon of ethanol produced.

- Renewable Energy Credits (RECs) – Renewable energy power facilities that offset carbon are eligible to receive tradable, nontangible RECs for each mWh of clean energy they produce. These certificates can be traded in compliance or voluntary markets. The compliance markets are driven by various renewable portfolio standards that are active in 29 states. Electric utilities are required to produce a certain amount of electricity via renewable technologies and can use RECs to qualify under these standards. The price of RECs has been volatile in its short history, but Mascoma uses a conservative estimate of $10 per mWh.

- BCAP Program – The Biomass Crop Assistance Program, through the US Department of Agriculture (USDA), is intended to encourage the development of biomass feedstock markets for nonfood-based crops. Under the program, biomass suppliers that deliver materials to qualified biomass conversion facilities are eligible to receive matched payments from the USDA of up to $45 per bone-dry ton. These payments are intended to encourage the development of nonfood feedstocks, such as grasses and hardwood, as well to provide cost relief to biomass conversion facilities.

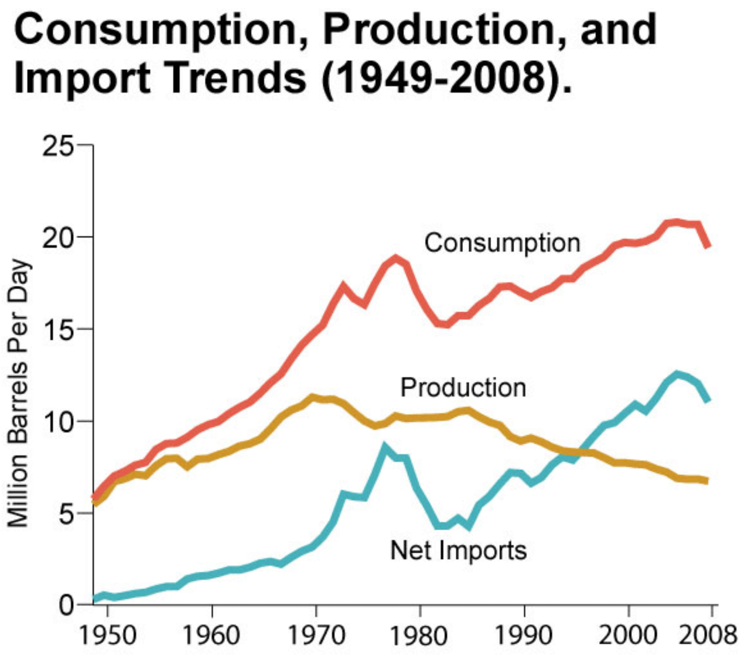
- Loan Guarantees – Several government programs provide loan guarantees through the federal government. Both the DOE and the USDA have programs in place for loan guarantees. In particular, the emerging technologies program through the DOE will provide government-backed loans for up to 70 percent of a project's capital costs. These loans usually are issued through a commercial bank, with the government as the final guarantor. These loan guarantees are highly competitive and require a significant due diligence process that can make for a long runway before projects can be put in place.

Conclusion

As Summa headed over to Salt hill Pub after the meeting, he reflected on the current state of Mascoma. The firm's successful R&D efforts to prove the concept of consolidated bioprocessing was cause for celebration. The company's investors were optimistic about the future, and the demonstration plant in Michigan was expected to provide the next step in scaling the company. But the company's ability to build out full-scale production was a concern. The current state of the capital markets meant debt financing was hard to obtain. Only firms that accessed the markets immediately prior to the recession had any funds available on hand to pursue commercial options. Summa also knew Mascoma's technology was far from being the industry standard. Numerous second-generation firms, backed by powerful venture capital funds, were vying to build plants, competing for government incentives, and looking to prove the competitive advantage of their technologies. And all of this was happening in a market that already was at overcapacity based on first-generation technologies.

Even as a startup with considerable capital infused into it, Mascoma still had limited financial flexibility to pursue a wide range of projects in attempting to commercialize its technology. Summa knew the project he recommended to the CFO and the board could have a significant effect on the success of Mascoma's commercialization efforts (see Exhibit 17 for a summary of the projects). As he stepped into Salt hill Pub, he felt as if he could finally relax a little, but he knew he had a big decision to make in the days ahead.

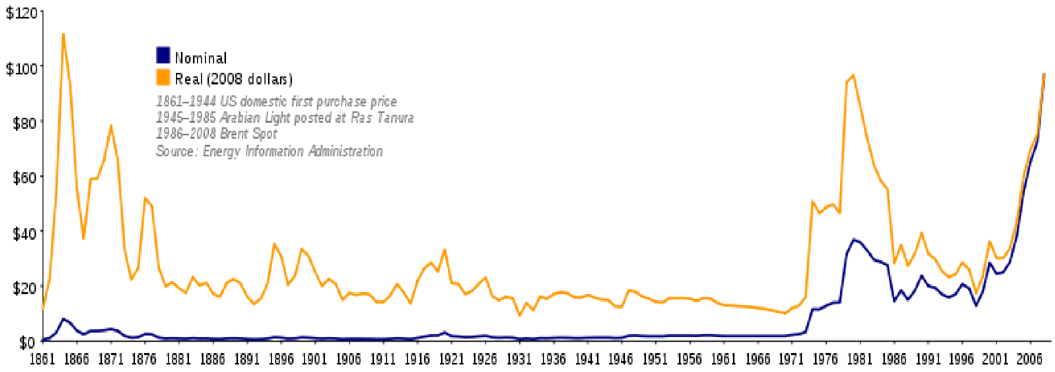
Exhibit 1 Petroleum Consumption, Production, and Import Trends, 1949–2008



Consumption, Production, and Import Trends (1949-2008).

Source: Energy Information Administration, *Annual Energy Review*, Table 5.1. (June 2008)

Exhibit 2 Nominal and Real Prices, Petroleum, 1861–2008



1861–1944 US domestic first purchase price
1945–1985 Arabian Light posted at Ras Tanura
1986–2008 Brent Spot
Source: Energy Information Administration

Exhibit 3 Food Prices and Global Maize Use

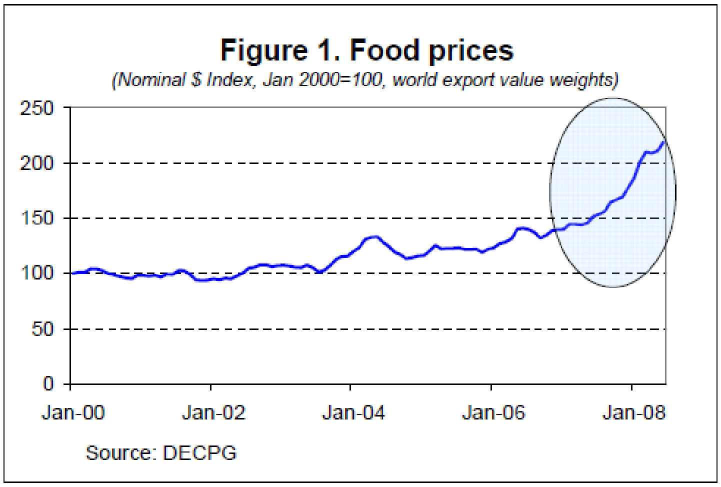


Figure 1. Food prices

(Nominal $ Index, Jan 2000=100, world export value weights)

Source: DECPG

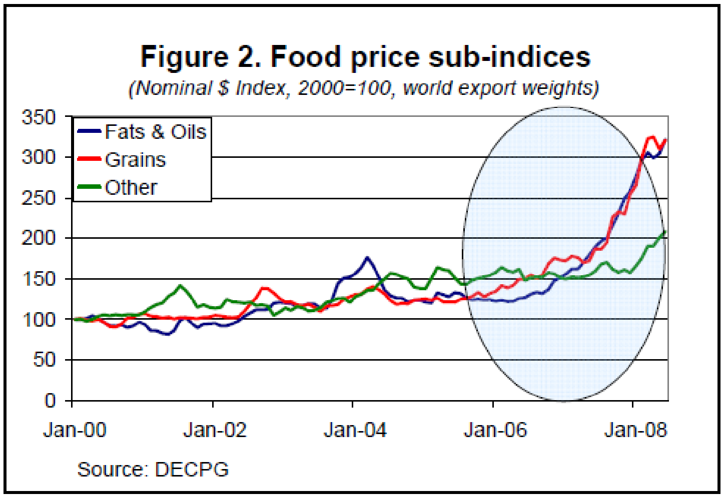


Figure 2. Food price sub-indices

(Nominal $ Index, 2000=100, world export weights)

Source: DECPG

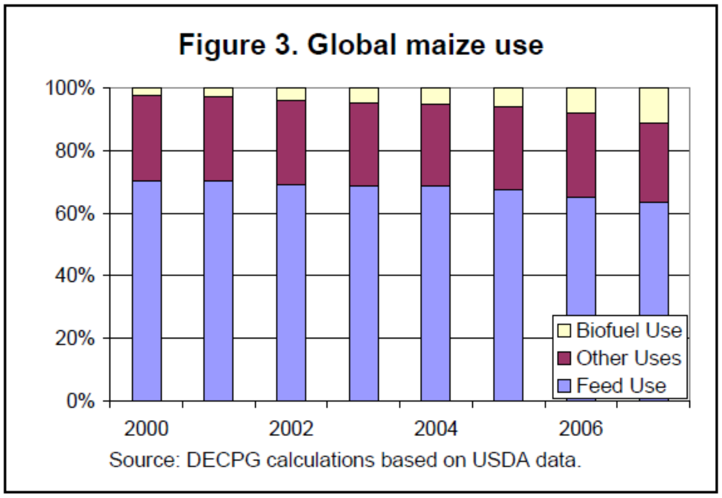


Figure 3. Global maize use

Source: DECPG calculations based on USDA data.

Exhibit 4 Sources of Mascoma Funding

Equity and Debt Financing to Date *($ MM)*

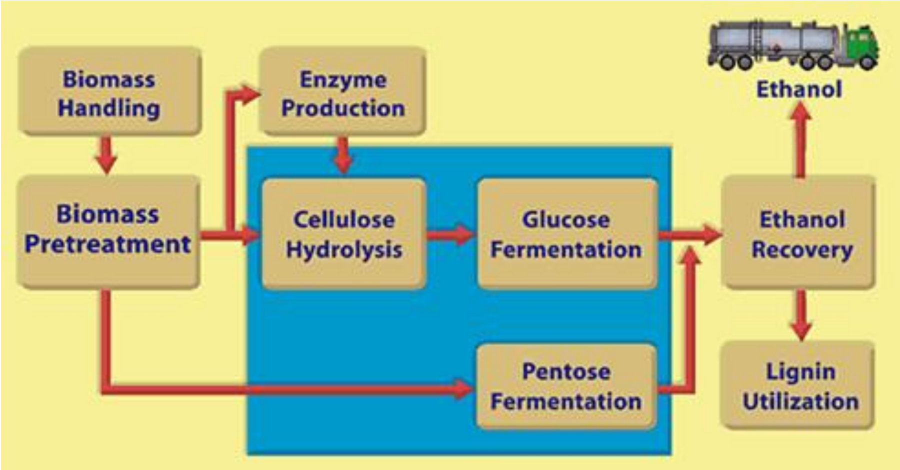
Date	Stage	# of Investors	Equity Amount	Debt Amount	Investors
March 2006	Seed	1	$4.00		Khosla Ventures
September 2006	Early Stage	1	$1.25		Flagship Ventures
November 2006	Expansion	8	$30.00		Atlas Ventures, Kleiner Perkins, Flagship Ventures, VantagePoint Venture Partners, General Catalyst Partners, Pinnacle Ventures, Khosla Ventures
March 2008	Later Stage	15	$45.00	$20.00	Atlas Ventures, Kleiner Perkins, VantagePoint Venture Partners, General Catalyst Partners, Pinnacle Ventures, Khosla Ventures
May 2008	Later Stage	5	$16.00		Kleiner Perkins, Flagship Ventures, General Catalyst Partners, Khosla Ventures
May 2008	Research & Development	1	$10.00		Marathon Oil
May 2008	Research & Development	1	Undisclosed		General Motors

Grant Funding to Date *($ MM)*

Date	Amount	Granter
January 2007	$14.80	New York State Department of Agriculture and Markets and New York State Energy Research and Development Authority
Undisclosed	$4.90	U.S. Department of Energy
October 2008	$26.00	U.S. Department of Energy
October 2008	$23.50	State of Michigan (Michigan Economic Development Services)

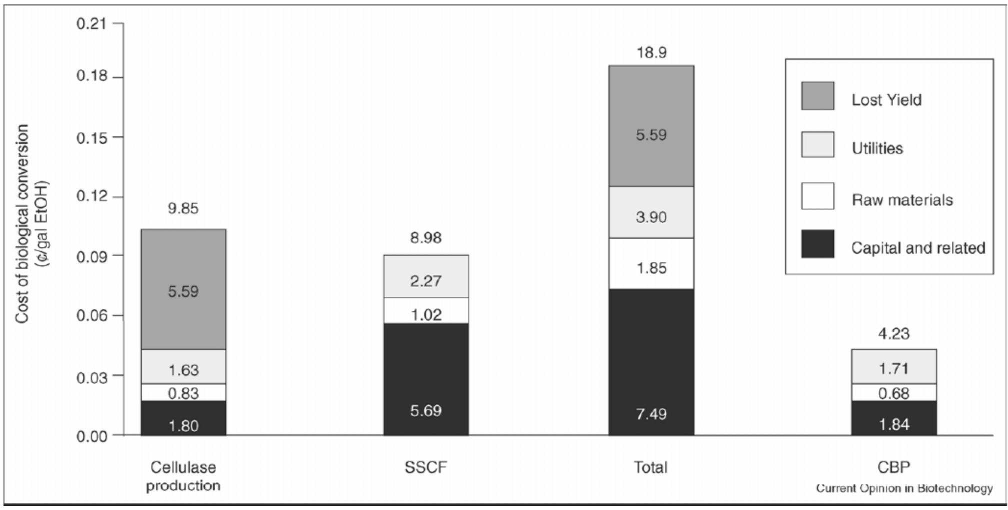
Source: VentureXpert and Mascoma Corporation website

Exhibit 5 Ethanol Fermentation Process Flow



Source: National Renewable Energy Laboratory (NREL)

Exhibit 6 Comparative Cost of Ethanol Production by CBP and SSCF with Dedicated Cellulase Production



[46]

Source: Lynd LR, van Zyl WH, McBride JE, Laser M. (2005). Consolidated Bioprocessing of Cellulosic Biomass: An Update. *Current Opinion in Biotechnology*, 16(5).

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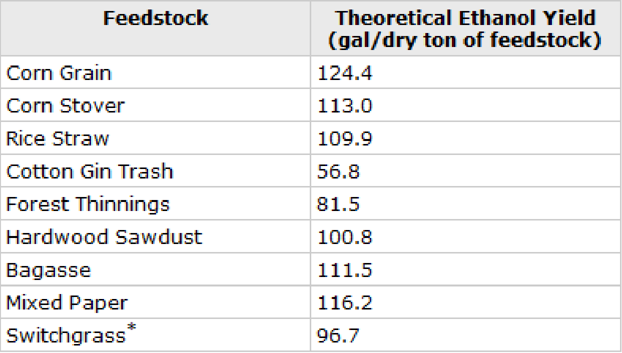
[46] SSCF: Simultaneous saccharification and co-fermentation, CBP: Consolidated Bioprocessing.

Exhibit 7 Comparison of Biomass Feedstocks

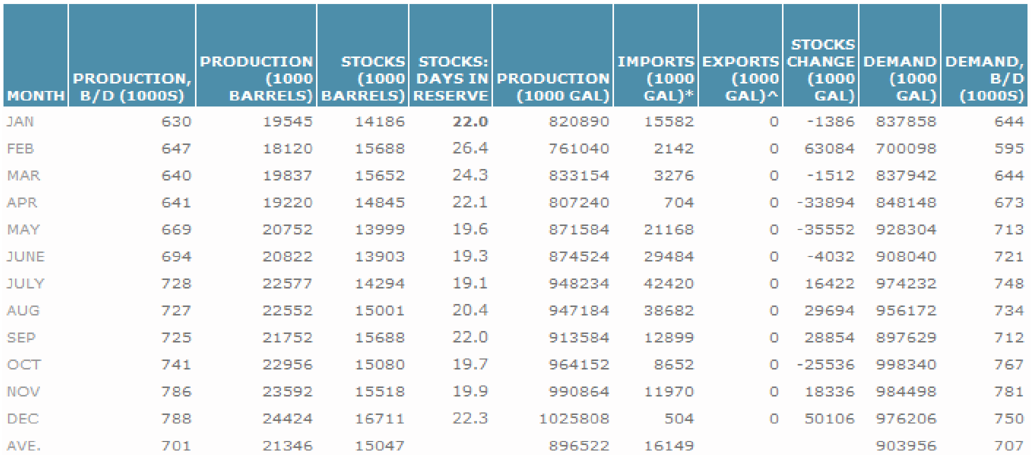


Feedstock	Theoretical Ethanol Yield (gal/dry ton of feedstock)
Corn Grain	124.4
Corn Stover	113.0
Rice Straw	109.9
Cotton Gin Trash	56.8
Forest Thinnings	81.5
Hardwood Sawdust	100.8
Bagasse	111.5
Mixed Paper	116.2
Switchgrass*	96.7

		Cellulose (Percent)	Hemi-cellulose (Percent)	Lignin (Percent)	Extractives (Percent)
Bioenergy Feedstocks	Corn stover[a]	30 - 38	19 - 25	17 - 21	3.3 - 11.9
	Sweet sorghum	27	25	11	
	Sugarcane bagasse[a]	32 - 43	19 - 25	23 - 28	1.5 - 5.5
	Sugarcane leaves	b	b	b	
	Hardwood	45	30	20	
	Softwood	42	21	26	
	Hybrid poplar[a]	39 - 46	17 - 23	21 - 8	1.6 - 6.9
	Bamboo	41-49	24-28	24-26	
	Switchgrass[a]	31 - 34	24 - 29	17 - 22	4.9 - 24.0
	Miscanthus	44	24	17	
	Giant Reed	31	30	21	

Source: US Department of Energy

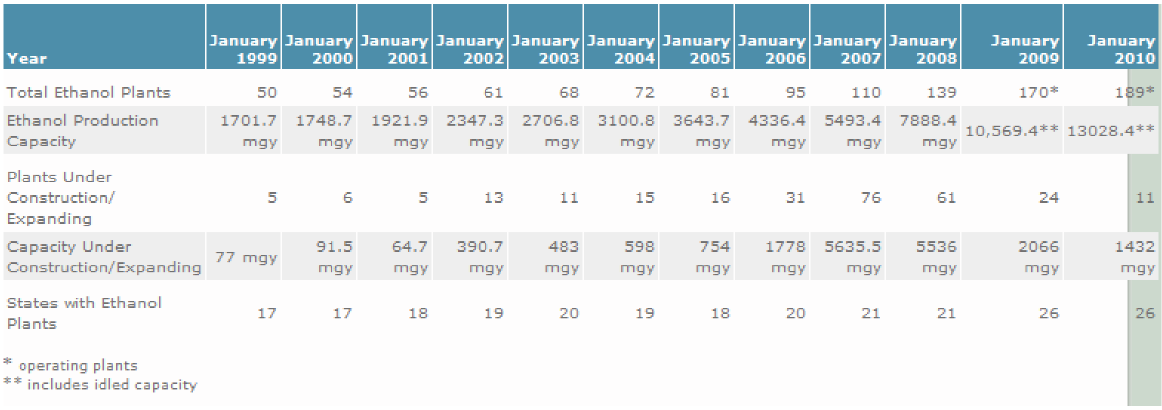
Exhibit 8 2009 Monthly US Fuel Ethanol Production and Demand



MONTH	PRODUCTION, B/D (1000S)	PRODUCTION (1000 BARRELS)	STOCKS (1000 BARRELS)	STOCKS: DAYS IN RESERVE	PRODUCTION (1000 GAL)	IMPORTS (1000 GAL)*	EXPORTS (1000 GAL)^	STOCKS CHANGE (1000 GAL)	DEMAND (1000 GAL)	DEMAND, B/D (1000S)
JAN	630	19545	14186	**22.0**	820890	15582	0	-1386	837858	644
FEB	647	18120	15688	26.4	761040	2142	0	63084	700098	595
MAR	640	19837	15652	24.3	833154	3276	0	-1512	837942	644
APR	641	19220	14845	22.1	807240	704	0	-33894	848148	673
MAY	669	20752	13999	19.6	871584	21168	0	-35552	928304	713
JUNE	694	20822	13903	19.3	874524	29484	0	-4032	908040	721
JULY	728	22577	14294	19.1	948234	42420	0	16422	974232	748
AUG	727	22552	15001	20.4	947184	38682	0	29694	956172	734
SEP	725	21752	15688	22.0	913584	12899	0	28854	897629	712
OCT	741	22956	15080	19.7	964152	8652	0	-25536	998340	767
NOV	786	23592	15518	19.9	990864	11970	0	18336	984498	781
DEC	788	24424	16711	22.3	1025808	504	0	50106	976206	750
AVE.	701	21346	15047		896522	16149			903956	707

Source: Renewable Fuels Association

Exhibit 9 Ethanol Industry Capacity and Expansion

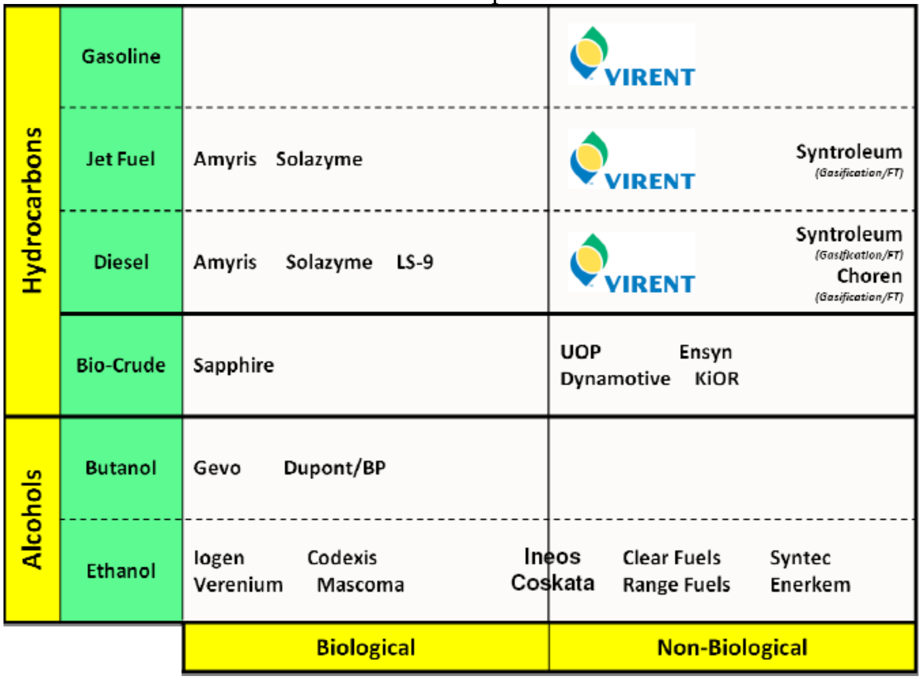


Year	January 1999	January 2000	January 2001	January 2002	January 2003	January 2004	January 2005	January 2006	January 2007	January 2008	January 2009	January 2010
Total Ethanol Plants	50	54	56	61	68	72	81	95	110	139	170*	189*
Ethanol Production Capacity	1701.7 mgy	1748.7 mgy	1921.9 mgy	2347.3 mgy	2706.8 mgy	3100.8 mgy	3643.7 mgy	4336.4 mgy	5493.4 mgy	7888.4 mgy	10,569.4**	13028.4**
Plants Under Construction/ Expanding	5	6	5	13	11	15	16	31	76	61	24	11
Capacity Under Construction/Expanding	77 mgy	91.5 mgy	64.7 mgy	390.7 mgy	483 mgy	598 mgy	754 mgy	1778 mgy	5635.5 mgy	5536 mgy	2066 mgy	1432 mgy
States with Ethanol Plants	17	17	18	19	20	19	18	20	21	21	26	26

* operating plants
** includes idled capacity

Source: Renewable Fuels Association

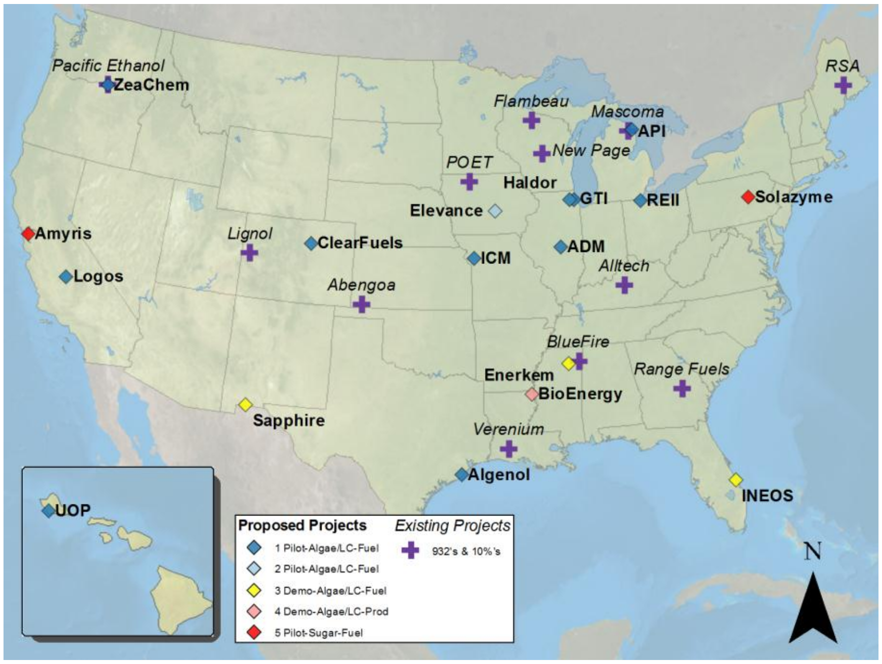
Exhibit 10 Second-Generation Biofuel Landscape



		Biological	Non-Biological
Hydrocarbons	Gasoline		VIRENT
	Jet Fuel	Amyris Solazyme	VIRENT Syntroleum (Gasification/FT)
	Diesel	Amyris Solazyme LS-9	VIRENT Syntroleum (Gasification/FT) Choren (Gasification/FT)
	Bio-Crude	Sapphire	UOP Ensyn Dynamotive KiOR
Alcohols	Butanol	Gevo Dupont/BP	
	Ethanol	Iogen Codexis Verenium Mascoma	Ineos Coskata Clear Fuels Range Fuels Syntec Enerkem

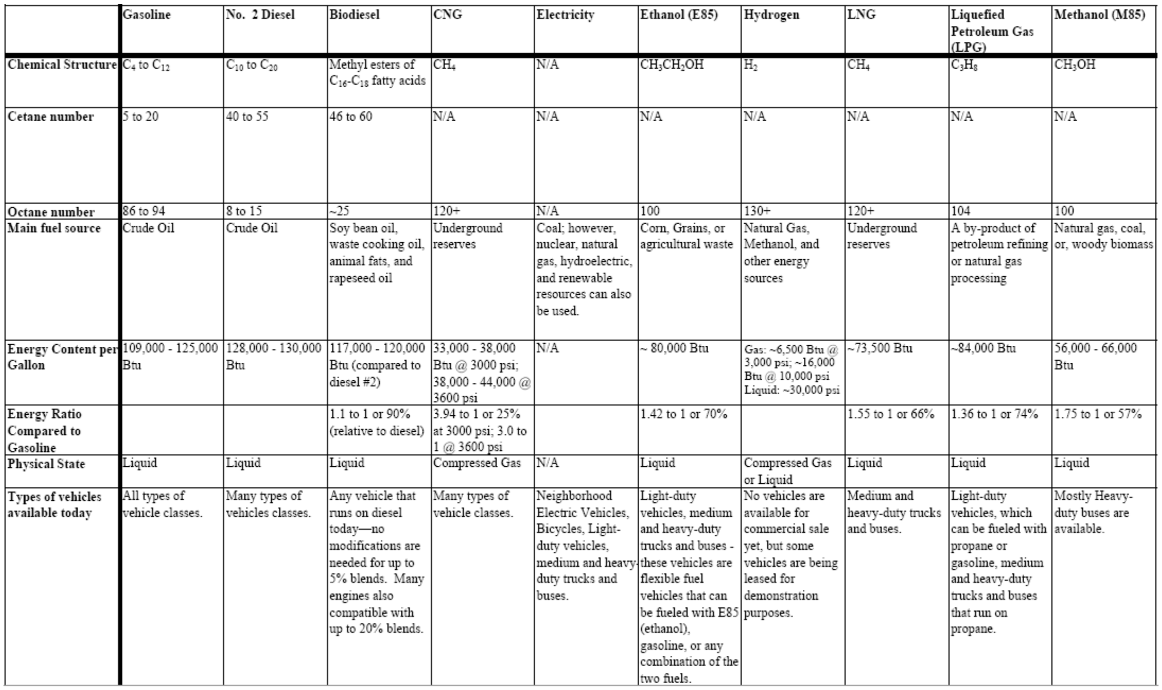
Source: Virent Energy Systems

Exhibit 11 Location of Second-Generation Pilot Plants Funded through DOE EERE Grant Program



Source: US Department of Energy

Exhibit 12 Comparison of Mobile Fuels



	Gasoline	**No. 2 Diesel**	**Biodiesel**	**CNG**	**Electricity**	**Ethanol (E85)**	**Hydrogen**	**LNG**	**Liquefied Petroleum Gas (LPG)**	**Methanol (M85)**
Chemical Structure	C_4 to C_{12}	C_{10} to C_{20}	Methyl esters of C_{16}-C_{18} fatty acids	CH_4	N/A	CH_3CH_2OH	H_2	CH_4	C_3H_8	CH_3OH
Cetane number	5 to 20	40 to 55	46 to 60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane number	86 to 94	8 to 15	~25	120+	N/A	100	130+	120+	104	100
Main fuel source	Crude Oil	Crude Oil	Soy bean oil, waste cooking oil, animal fats, and rapeseed oil	Underground reserves	Coal; however, nuclear, natural gas, hydroelectric, and renewable resources can also be used.	Corn, Grains, or agricultural waste	Natural Gas, Methanol, and other energy sources	Underground reserves	A by-product of petroleum refining or natural gas processing	Natural gas, coal, or, woody biomass
Energy Content per Gallon	109,000 - 125,000 Btu	128,000 - 130,000 Btu	117,000 - 120,000 Btu (compared to diesel #2)	33,000 - 38,000 Btu @ 3000 psi; 38,000 - 44,000 @ 3600 psi	N/A	~ 80,000 Btu	Gas: ~6,500 Btu @ 3,000 psi; ~16,000 Btu @ 10,000 psi Liquid: ~30,000 psi	~73,500 Btu	~84,000 Btu	56,000 - 66,000 Btu
Energy Ratio Compared to Gasoline			1.1 to 1 or 90% (relative to diesel)	3.94 to 1 or 25% at 3000 psi; 3.0 to 1 @ 3600 psi		1.42 to 1 or 70%		1.55 to 1 or 66%	1.36 to 1 or 74%	1.75 to 1 or 57%
Physical State	Liquid	Liquid	Liquid	Compressed Gas	N/A	Liquid	Compressed Gas or Liquid	Liquid	Liquid	Liquid
Types of vehicles available today	All types of vehicle classes.	Many types of vehicles classes.	Any vehicle that runs on diesel today—no modifications are needed for up to 5% blends. Many engines also compatible with up to 20% blends.	Many types of vehicle classes.	Neighborhood Electric Vehicles, Bicycles, Light-duty vehicles, medium and heavy-duty trucks and buses.	Light-duty vehicles, medium and heavy-duty trucks and buses - these vehicles are flexible fuel vehicles that can be fueled with E85 (ethanol), gasoline, or any combination of the two fuels.	No vehicles are available for commercial sale yet, but some vehicles are being leased for demonstration purposes.	Medium and heavy-duty trucks and buses.	Light-duty vehicles, which can be fueled with propane or gasoline, medium and heavy-duty trucks and buses that run on propane.	Mostly Heavy-duty buses are available.

Source: US Department of Energy

Exhibit 13 Baseline Project Financials

($ MM)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
INCOME STATEMENT									
Revenues									
Ethanol sales	$0.0	$0.0	$115.6	$120.2	$125.0	$130.0	$135.2	$140.6	$146.3
Recycle material sales	$0.0	$0.0	$22.3	$22.9	$23.6	$24.3	$25.1	$25.8	$26.6
Power/Electricity sales	$0.0	$0.0	$57.3	$59.0	$60.8	$62.6	$64.5	$66.4	$68.4
TOTAL REVENUES	$0.0	$0.0	$195.2	$202.2	$209.4	$217.0	$224.8	$232.9	$241.3
Operating expenses									
Feedstock cost	$0.0	$0.0	$40.6	$42.2	$43.9	$45.6	$47.4	$49.3	$51.3
TOTAL COGS	$0.0	$0.0	$96.3	$99.3	$124.5	$128.6	$133.0	$137.4	$142.0
TOTAL SALES EXPENSE	$0.0	$0.0	$5.8	$6.0	$6.3	$6.5	$6.8	$7.0	$7.3
INCOME FROM OPERATIONS	$0.0	$0.0	$93.1	$96.8	$78.7	$81.8	$85.1	$88.4	$91.9
Revenues from government incentives									
Treasury grant	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Carbon credits	$0.0	$0.0	$7.7	$7.8	$7.8	$7.8	$7.9	$7.9	$7.9
RIN credits	$0.0	$0.0	$12.1	$12.1	$12.2	$12.2	$12.3	$12.4	$12.4
Renewable energy certificates (RECs)	$0.0	$0.0	$5.6	$5.6	$5.7	$5.7	$5.8	$5.8	$5.9
TOTAL REVENUES FROM GOVERNMENT INCENTIVES	$0.0	$0.0	$25.3	$25.5	$25.6	$25.8	$26.0	$26.1	$26.3
TOTAL INDIRECT EXPENSE	$10.0	$6.7	$6.8	$7.0	$7.2	$7.4	$7.6	$7.9	$8.1
EBITDA	($10.0)	($6.7)	$111.7	$115.3	$97.2	$100.2	$103.4	$106.7	$110.1
Depreciation	$0.0	$0.0	$22.3	$22.4	$22.6	$22.8	$22.9	$23.1	$23.2
EBIT	($10.0)	($6.7)	$89.4	$92.9	$74.6	$77.5	$80.5	$83.6	$86.8
Interest bank debt	$0.0	($0.1)	$10.7	$7.5	$4.7	$2.5	$0.0	$0.0	$0.0
EBT	($10.0)	($6.6)	$78.7	$85.4	$69.9	$74.9	$80.5	$83.6	$86.8
Taxes									
Tax basis	($10.0)	($6.6)	$78.7	$85.4	$69.9	$74.9	$80.5	$83.6	$86.8
Income tax expense/(net operating loss carryforward)	($3.5)	($2.3)	$27.5	$29.9	$24.5	$26.2	$28.2	$29.3	$30.4
Applied net operating loss carryforwards	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Ethanol PTC credits	$0.0	$0.0	($27.0)	($27.1)	($27.3)	($27.4)	($27.5)	($27.7)	($27.8)
Power/Electricity PTC credits	$0.0	$0.0	($6.5)	($6.7)	($6.9)	($7.1)	($7.3)	($7.5)	($7.8)
Applied ethanol PTC credits	$0.0	$0.0	($27.0)	($27.1)	($24.5)	($26.2)	($28.2)	($29.3)	($29.6)
Applied power/electricity PTC credits	$0.0	$0.0	($0.5)	($2.7)	$0.0	$0.0	$0.0	$0.0	($0.8)
TOTAL TAX EXPENSE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
NET INCOME (LOSS)	($10.0)	($6.6)	$78.7	$85.4	$69.9	$74.9	$80.5	$83.6	$86.8
CASH FLOW ITEMS									
Capital expenditures	($203.3)	($141.9)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)
Proceeds from bank debt	$103.1	$95.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Repayment of bank debt	$0.0	$0.0	($65.7)	($64.4)	($55.8)	($12.3)	$0.0	$0.0	$0.0
Proceeeds from preferred equity	$110.2	$93.5	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Proceeds from common equity	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
PROJECT VALUATION									
Cash flow from operations with interest and government incentives	($6.5)	($33.9)	$168.2	$113.6	$94.3	$96.7	$100.3	$103.6	$107.0
Capital expenditures	($203.3)	($141.9)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)
Free cash flows	($209.8)	($175.8)	$165.8	$111.2	$91.9	$94.3	$97.9	$101.2	$104.6

WACC	15.3%
IRR	25.4%
NPV	$169.3

Exhibit 14 Sugarcane Bagasse Project Financials

($ MM)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
INCOME STATEMENT									
Revenues									
Ethanol sales	$0.0	$0.0	$0.0	$67.3	$70.0	$72.8	$75.7	$78.8	$81.9
Recycle material sales	$0.0	$0.0	$0.0	$4.6	$4.7	$4.9	$5.0	$5.2	$5.3
Power/Electricity sales	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
TOTAL REVENUES	$0.0	$0.0	$0.0	$71.9	$74.7	$77.7	$80.7	$83.9	$87.2
Operating expenses									
Feedstock cost	$0.0	$0.0	$0.0	$7.9	$8.2	$8.5	$8.9	$9.2	$9.6
TOTAL COGS	$0.0	$0.0	$0.0	$35.8	$37.0	$42.4	$43.7	$45.1	$46.6
TOTAL SALES EXPENSE	$0.0	$0.0	$0.0	$3.4	$3.5	$3.6	$3.8	$3.9	$4.1
INCOME FROM OPERATIONS	$0.0	$0.0	$0.0	$32.7	$34.3	$31.7	$33.2	$34.9	$36.6
Revenues from government incentives									
Treasury grant	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Carbon credits	$0.0	$0.0	$0.0	$4.3	$4.4	$4.4	$4.4	$4.4	$4.5
RIN credits	$0.0	$0.0	$0.0	$6.8	$6.8	$6.9	$6.9	$6.9	$7.0
Renewable energy certificates (RECs)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
TOTAL REVENUES FROM GOVERNMENT INCENTIVES	$0.0	$0.0	$0.0	$11.1	$11.2	$11.2	$11.3	$11.3	$11.4
TOTAL INDIRECT EXPENSE	$0.0	$3.2	$2.1	$2.5	$2.6	$2.7	$2.8	$2.8	$2.9
EBITDA	$0.0	($3.2)	($2.1)	$41.3	$42.9	$40.2	$41.8	$43.4	$45.0
Depreciation	$0.0	$0.0	$0.0	$7.0	$7.1	$7.2	$7.2	$7.3	$7.4
EBIT	$0.0	($3.2)	($2.1)	$34.3	$35.8	$33.1	$34.5	$36.1	$37.7
Interest bank debt	$0.0	$0.0	$0.0	$5.1	$3.8	$2.6	$1.6	$0.0	$0.0
EBT	$0.0	($3.2)	($2.1)	$29.2	$32.0	$30.5	$33.0	$36.1	$37.7
Taxes									
Tax basis	$0.0	($3.2)	($2.1)	$29.2	$32.0	$30.5	$33.0	$36.1	$37.7
Income tax expense/(net operating loss carryforward)	$0.0	($1.1)	($0.7)	$10.2	$11.2	$10.7	$11.5	$12.6	$13.2
Applied net operating loss carryforwards	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Ethanol PTC credits	$0.0	$0.0	$0.0	($15.2)	($15.3)	($15.3)	($15.4)	($15.5)	($15.6)
Power/Electricity PTC credits	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Applied ethanol PTC credits	$0.0	$0.0	$0.0	($10.2)	($11.2)	($10.7)	($11.5)	($12.6)	($13.2)
Applied power/electricity PTC credits	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
TOTAL TAX EXPENSE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
NET INCOME (LOSS)	$0.0	($3.2)	($2.1)	$29.2	$32.0	$30.5	$33.0	$36.1	$37.7
CASH FLOW ITEMS									
Capital expenditures	$0.0	($64.5)	($45.9)	($1.0)	($1.0)	($1.0)	($1.0)	($1.0)	($1.0)
Proceeds from bank debt	$0.0	$39.1	$53.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Repayment of bank debt	$0.0	$0.0	$0.0	($24.7)	($24.9)	($24.3)	($18.1)	$0.0	$0.0
Proceeeds from preferred equity	$0.0	$28.5	$35.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Proceeds from common equity	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
PROJECT VALUATION									
Cash flow from operations with interest and government incentives	$0.0	($2.1)	($11.9)	$57.7	$40.9	$38.2	$39.9	$42.4	$44.0
Capital expenditures	$0.0	($64.5)	($45.9)	($1.0)	($1.0)	($1.0)	($1.0)	($1.0)	($1.0)
Free cash flows	$0.0	($66.6)	($57.8)	$56.7	$39.9	$37.2	$38.9	$41.4	$43.0

WACC	12.9%
IRR	30.2%
NPV	$100.7

Source: Authors, generalized from information provided by Mascoma Corporation

Exhibit 15 Alberta Hardwood Greenfield Project Financials

($ MM)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
INCOME STATEMENT									
Revenues									
Ethanol sales	$0.0	$0.0	$102.8	$106.9	$111.1	$115.6	$120.2	$125.0	$130.0
Recycle material sales	$0.0	$0.0	$19.0	$19.6	$20.2	$20.8	$21.4	$22.1	$22.7
Power/Electricity sales	$0.0	$0.0	$60.5	$62.3	$64.2	$66.1	$68.1	$70.1	$72.2
TOTAL REVENUES	$0.0	$0.0	$182.3	$188.8	$195.5	$202.5	$209.7	$217.2	$225.0
Operating expenses									
Feedstock cost	$0.0	$0.0	$32.1	$33.4	$34.7	$36.1	$37.6	$39.1	$40.6
TOTAL COGS	$0.0	$0.0	$112.9	$116.6	$120.4	$124.4	$128.5	$132.7	$137.1
TOTAL SALES EXPENSE	$0.0	$0.0	$5.1	$5.3	$5.6	$5.8	$6.0	$6.3	$6.5
INCOME FROM OPERATIONS	$0.0	$0.0	$64.3	$66.8	$69.5	$72.3	$75.2	$78.3	$81.4
Revenues from government incentives									
Treasury grant	$0.0	$0.0	$25.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Carbon credits	$0.0	$0.0	$7.7	$7.8	$7.8	$7.8	$7.9	$7.9	$7.9
RIN credits	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Renewable energy certificates (RECs)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
TOTAL REVENUES FROM GOVERNMENT INCENTIVES	$0.0	$0.0	$32.7	$7.8	$7.8	$7.8	$7.9	$7.9	$7.9
TOTAL INDIRECT EXPENSE	$10.0	$6.7	$6.8	$7.0	$7.2	$7.4	$7.6	$7.9	$8.1
EBITDA	($10.0)	($6.7)	$90.2	$67.6	$70.1	$72.8	$75.5	$78.3	$81.3
Depreciation	$0.0	$0.0	$22.3	$22.4	$22.6	$22.8	$22.9	$23.1	$23.2
EBIT	($10.0)	($6.7)	$67.9	$45.2	$47.5	$50.0	$52.6	$55.2	$58.0
Interest bank debt	$0.0	$0.0	$6.5	$4.0	$2.5	$1.1	$0.5	$0.0	$0.0
EBT	($10.0)	($6.7)	$61.4	$41.2	$45.0	$48.8	$52.0	$55.2	$58.0
Taxes									
Tax basis	($10.0)	($6.7)	$36.4	$41.2	$45.0	$48.8	$52.0	$55.2	$58.0
Income tax expense/(net operating loss carryforward)	($3.5)	($2.3)	$12.8	$14.4	$15.7	$17.1	$18.2	$19.3	$20.3
Applied net operating loss carryforwards	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Ethanol PTC credits	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Power/Electricity PTC credits	$0.0	$0.0	($12.5)	($12.8)	($13.2)	($13.6)	($14.0)	($14.4)	($14.9)
Applied ethanol PTC credits	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Applied power/electricity PTC credits	$0.0	$0.0	($12.5)	($12.8)	($13.2)	($13.6)	($14.0)	($14.4)	($14.9)
TOTAL TAX EXPENSE	$0.0	$0.0	$0.3	$1.6	$2.5	$3.5	$4.2	$4.9	$5.4
NET INCOME (LOSS)	($10.0)	($6.7)	$61.1	$39.6	$42.5	$45.4	$47.8	$50.3	$52.6
CASH FLOW ITEMS									
Capital expenditures	($202.0)	($137.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)
Proceeds from bank debt	$101.8	$90.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Repayment of bank debt	$0.0	$0.0	($70.9)	($48.8)	($36.0)	($32.9)	($3.8)	$0.0	$0.0
Proceeeds from preferred equity	$110.2	$93.5	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Proceeds from common equity	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
PROJECT VALUATION									
Cash flow from operations with interest and government incentives	($6.5)	($32.5)	$150.5	$67.9	$67.0	$67.2	$67.8	$70.4	$72.8
Capital expenditures	($202.0)	($137.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)	($2.4)
Free cash flows	($208.5)	($169.9)	$148.1	$65.5	$64.5	$64.7	$65.3	$68.0	$70.4

WACC	14.5%
IRR	17.7%
NPV	$49.1

Source: Authors, generalized from information provided by Mascoma Corporation

Exhibit 16 Product Commercialization Project Financials

		Base Plant		**Base Plant - w/Mascoma products**	
Gallons of ethanol produced	*millions of gallons*	97.85		103.72	
		dollars (000	*per gallon*	*dollars (000*	*per gallon*
Revenues					
Detatured ethanol sales		195,700.0	2.0000	207,442.0	2.0000
Cellulosic ethanol credit		-	-	-	-
DDGs		40,364.3	0.4125	35,724.5	0.3444
CO2		1,989.1	0.0203	2,108.4	0.0203
Total revenues		238,053.4	2.4328	245,274.9	2.3648
Costs					
Materials					
Feedstock		138,181.8	1.4122	138,181.8	1.3322
Enzymes					
Alpha-amylase		1,596.0	0.0163	1,596.0	0.0154
Glucoamylase		1,828.1	0.0187	-	-
Subtotal enzymes		3,424.1	0.0350	1,596.0	0.0154
Yeast		243.8	0.0025	243.8	0.0024
SO2		3,500.0	0.0358	3,500.0	0.0337
Denaturant		5,700.0	0.0583	6,042.0	0.0583
Subtotal materials		151,049.7	1.5437	149,563.6	1.4420
Energy and water					
Thermal		18,572.5	0.1898	18,529.3	0.1786
Electricity		5,320.0	0.0544	5,639.2	0.0544
Water		565.3	0.0058	599.2	0.0058
Subtotal energy and water		24,457.8	0.2500	24,767.6	0.2388
Indirect costs					
Labor		6,500.0	0.0664	6,500.0	0.0627
Insurance and taxes		8,000.0	0.0818	8,000.0	0.0771
License fees		5,000.0	0.0511	5,000.0	0.0482
Maintenance		5,000.0	0.0511	5,000.0	0.0482
Other		2,500	0.0255	2,500	0.0241
Subtotal indirect costs		27,000.0	0.2759	27,000.0	0.2603
Total costs (prior to CBP premium)		202,507.47	2.0696	201,331.21	1.9411
EBITDA (prior to CBP premium)		35,545.89	0.3633	43,943.69	0.4237
Premium paid for CBP				2,771.3	0.0267
EBITDA		35,545.89	0.3633	41,172.41	0.3970
Total costs (prior to CBP premium)		202,507.47	2.0696	201,331.21	1.9411
less DDGs, CO2, and Cellulosic revs		(42,353.35)	(0.4328)	(37,832.90)	(0.3648)
Total costs showing revenue as credits		160,154.11	**1.6367**	163,498.31	**1.5763**
Total Value created				8,397.80	0.0810
Customer Value				5,626.53	0.0542
Customer capture of value created				*67.0%*	
Increase in customer earnings				*15.8%*	
Price paid for yeast (with premium)					
Yeast used	*thousands of pounds*	162.50		162.50	
Yeast expense	*thousands of dollars*	243.75		3,015.03	
Yeast cost / price	*dollars per pound*	1.50		18.55	

Source: Authors, generalized from information provided by Mascoma Corporation

Exhibit 17 Product Commercialization Project Financials